Utility Model H7-39120

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Title of Invention: LED Drive Circuit

Abstract

Purpose: To fix the light emission brightness of multiple light emitting diodes (LED), while at the same time preventing the supply of high current to other LEDs when a given LED is in an open state.

Constitution: 2 or more light emitting diodes (LED1, LED2) are connected in two rows, with transistors TR1, TR2 connected to each LED respectively as a current regulating device. The base voltage of these transistors is controlled by an op-amp OP; a fixed voltage VIN is input to one of the input terminals on this op amp and the emitter voltage V1 from the transistor TR1 is input to the other input terminal, and a resistor R3 is further connected between the op amp output and the base. By provision of this resistor R3, when one LED is in an open state, a rise in base voltage on the transistor connected to the other LED is prevented, as is the incidence of high currents.

Utility Model Claims

1. An LED drive circuit characterized in that in an LED drive circuit in which 2 or more LEDs are connected in 2 rows, and a current limiting device is connected to each row of LEDs, respectively, so as to limit the drive current to each LED, an op amp is provided to control the current limiting element, with a fixed voltage input to one of the input terminals of the op amp, and a voltage generated based on the current which flows on one of the current regulating devices on the other [op amp] input terminal. Further, a resistor is connected between the op amp output terminal and the current regulating device control input terminal.

Claim 2: The LED drive control circuit of Claim 1, characterized in that 2 current regulating devices are respectively constituted of bipolar devices of identical specification; LEDs are respectively placed between each collector and a power supply at one potential, and resistors are respectively connected between each

emitter and a power supply at a different potential; each base is mutually connected, while at the same time the op amp output terminal is connected through a resistor to the base, and one of the transistor emitters is connected to the other op amp input terminal.

Claim 3. The LED drive circuit of Claim 2, in which the resistance value of the resistor placed between the op amp output terminal and the transistor base is set to be sufficiently higher than the resistance value of the resistor connected to the transistor emitter.

Brief Description of Figures

Fig. 1. An overview circuit diagram of one embodiment of the LED drive circuit of the present Utility Model.

Fig. 2. An equivalent circuit diagram to explain the current value on the other LED when one LED goes to an open state.

Fig. 3. A circuit diagram for the case in which the base of the current regulating device of the present utility model is not connected.

Fig. 4. An equivalent circuit diagram to explain the current value of the other LED when one LED in the Fig. 3 circuit goes to an open state.

Fig. 5. A circuit diagram of the main sections of another embodiment of the present utility model.

Fig. 6. A summary diagram of a bar code reader using an LED as light source.

Fig. 7. A partial circuit diagram of one example of a conventional LED drive circuit.

Fig. 8. An equivalent circuit diagram to explain the current value on the other LED when one LED in the Fig. 7 circuit goes to an interrupted state.

Reference Numerals

LED1, LED2: Light emitting diode rows (LED rows)
OP: Op amp
TR1, TR2: Transistors (current regulating devices)
R1-R3: Resistors
2: LED
4: LED drive circuit
5: Lens
6: Bar code
7: CCD line sensor
8: Signal processing circuit.

Detailed Description of the Utility Model

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Industrial Field of Application

The present utility model relates to a drive circuit for causing an LED (light emitting diode) to emit light. In particular, it relates to an LED drive circuit for causing multiple LEDs to emit light at a fixed brightness.

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Prior Art

In general, when arraying multiple LEDs for use in a surface light source, it is necessary to cause each LED to emit light at a fixed brightness. For example, Fig. 6 is a conceptual diagram of a bar code reader using LEDs as a light source; multiple LED2s are arrayed on a substrate 1, which is placed in a bar code reader housing 3 and connected to a drive circuit 4 and caused to emit light. Emitted light refers to a bar code 6 through a lens 5, and the reflected light therefrom is received by a CCD line sensor 7. An electrical level signal is output from this CCD line sensor 7 based on the difference in reflected light from the respective black and white bars of the bar code, thus enabling the bar code to be read by processing of the electrical signal in a processing circuit 8.

Thus, when arraying multiple LEDs and using them as a planar light source, if the brightness of each LED is not uniform, the brightness of the illuminated bar code will not be uniform, resulting in a variation in the amount of reflected light from black and white bars and read errors by the CCD line sensor.

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For this reason, a current regulating circuit has conventionally been provided in the LED drive circuit in order to maintain a fixed LED emitted light brightness even when power source voltage fluctuates, such that multiple LEDs can be caused to emit a fixed and uniform light by holding fixed the current supplied to the LEDs. However, because of the need to regulate all the current supplied to multiple LEDs in this fixed current circuit, the size of the circuit becomes large in scale, making it undesirable for use in the compact, portable type of bar code reader shown in Fig. 6.

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It has therefore been proposed in the past to use a circuit which achieves LED current regulation with an op amp. Fig. 7 is such an example; multiple LEDs – in this case LED rows LED1 and LED2 in which 2 LEDs are respectively directly connected – are then respectively connected to the collectors and emitters of the current regulating transistors TR1 and TR2. By supplying a fixed voltage to each base of these transistors TR1 and TR2, regulation of the current supplied to each LED1 and LED2 was achieved. Here the regulated voltage supply comprises an op amp OP, with the input voltage VIN and the emitter voltage V1 of one of the

transistors TR1 serving respectively as the positive phase input and negative phase input. Resistors R1 and R2 are respectively connected to the emitters of each transistor TR1 and TR2.

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With this constitution, the positive phase input terminal and negative phase input terminal of the op amp OP [form a] virtual short, such that VIN = V1, and the currents I11, I12 flowing at each LED1 and 2 are equal, as are the emitted light brightnesses of LED1 and LED2.

In Fig. 7, each LED1 and LED**12** [*sic?*] are connected in LED rows, but the same applies to [devices] comprised of single individual LEDs.

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Problems the Utility Model Seeks to Resolve

Thus, in drive circuits using op amps, a malfunction on one LED (or LED row; the two shall be treated as equal below) results in the flow of a higher than setting current to the other LED. Detailed reasons are described below, but this means that when one LED is in an open state due to malfunction or maintenance, etc., the output voltage on the op amp will rise to close to the power supply voltage, and the large current determined by this voltage and by the transistor and resistor connected to the other LED[s] will flow to the other LED, causing the LED brightness to fluctuate, thus degrading bar code reading performance or breaking the LED as a result of this large current.

The object of the present utility model is to provide an LED drive circuit which regulates the emitted light brightness of multiple LEDs, while preventing the supply of large currents to other LEDs even when one LED goes to an open state.

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Means for Resolving Problem

In the LED drive circuit of the present utility model, 2 or more LEDs are connected in 2 rows, with the LEDs of each row respectively connected to a current controlling element, such that the LED drive circuit controls the drive current to each LED by current controlling elements. An op amp is provided which controls the current controlling elements; a fixed voltage is input to one of the input elements of this op amp, and a voltage generated based on the current flowing at one of the current controlling elements is input to the other input terminal; a resistor is connected between the op amp output terminal and the current regulating device control input terminal.

For example, 2 current regulating devices comprise bipolar transistors of the same specification, with LEDs respectively connected between the collector of each and a power supply at one potential, and a resistor respectively connected between the emitter of each and a power supply at another potential; each base is mutually directly connected, while the op amp output terminal is connected to the base through a resistor, and one of the transistor emitters is connected to the other input terminal of the op amp.

In this case, a design is adopted such that the resistance value of the resistor connected between the op amp output terminal and the transistor base is sufficiently larger than the resistance value of the resistor connected to the transistor emitter.

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Embodiment

Next we shall explain the present utility model with reference to figures. Fig. 1 is a circuit diagram of an embodiment of the LED drive circuit of the present utility model. It shows, as an example, the case of an LED drive circuit used in a light source for a bar code reader. Transistors TR3 and TR4 and resistors R4-R7 comprise the switching circuit section; when the ON/OFF signal which causes the LED to emit light is input to the drive signal input terminal IN connected to the base of transistor TR3, [the configuration] is constituted such that the power supply voltage VCC is output to the power supply line connected to the collector of transistor TR4. 2 LED rows of multiple (in this case 2) cascaded LEDs, that is to say LED1 and LED2, are respectively parallel connected to this power supply line, and the collectors of current controlling transistors TR1 and TR2, the bases of which are mutually directly connected, are connected to LED 1 and LED2 respectively, with each emitter respectively connected through resistors R1 and R2 to ground.

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At the same time, the voltage regulating circuit section is connected to the aforementioned power supply line. This voltage regulating circuit section has a voltage regulator IC, which maintains a specified voltage supplied on the aforementioned power supply line, and regulates the output voltage VO thereof. Also, the voltage regulator IC output voltage VO is voltage divided by resistor R8 and R9, and the voltage-divided voltage VIN supplied to the op amp OP positive phase input terminal. Resistor R3 is directly connected to the output terminal of op amp OP, and the output of op amp OP is supplied to the each of the aforementioned transistors TR1, TR2 through the resistor R3. Also, the emitter of one of the transistors TR1 is connected to the reverse phase input terminal of the op amp OP.

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According to this configuration, input of an ON signal at the drive signal input terminal IN causes transistors TR3, TR4 to go on, such that power supply voltage VCC is supplied to the power supply line. When this occurs, a fixed voltage VO is output from the voltage regulator IC, and the voltage VIN, divided by resistors R8, R9, is input to the positive phase input terminal of op amp OP. Voltage V2 is then output from the output terminal of op amp OP, and this voltage V2 is input to the base of transistors TR1, TR2 through the resistor R3. Controlling the collector/emitter currents on transistors TR1, TR2 enables control of the currents I1, I2 flowing to LED rows LED1 and LED2. When transistors having identical characteristics are used for TR1 and TR2, and identical resistance

values are used for resistors R1 and R2, the currents I1 and I2 respectively flowing to the LED rows LED1 and LED2 will be equal, and light of uniform brightness will be emitted from each LED row LED1 and LED2.

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That is to say, because the positive phase and reverse phase are virtually shorted, V1 = VIN, and a current I1, where I1 [*symbol unavailable*] "approximately. equals" VIN/R2, flows to LED row LED1. If resistor R1 = R2, the transistors TR1 and TR2 have a common base, and the voltage VBE across the base-emitter of each transistor will be equal, such that I2 = I1 in a current mirror configuration, and an equal current will flow to LED row LED2 as to LED1. As a result, an equal and fixed current will flow to LED1 and LED2, making it possible to maintain a fixed and uniform LED1 and LED2 brightness.

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For example, as shown in the respective parenthetical values for resistance and voltage in Fig. 1, if VIN = 0.5V; R1 = R2 = 33 , and transistor TR1 and TR2 VBE = 0.6V, then transistor TR1 and TR2 base voltage V3 will be V3 = V1 + VBE, and therefore
V3 = 0.5V + 0.6V = 1.1V.

From I1 *approximately equals* VIN/R2,
= 0./33,
we have
I1 = I2 *approximately equals* 15.2 mA.

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Here we consider the case in which one of the LED rows, for example LED1, goes to an open state, and the circuit is open. In this event, the Fig. 1 circuit becomes the equivalent circuit shown in Fig 2(a). Transistor TR1 is equivalent to a diode D1 with a Vf = 0.6V. Due to the virtual short, op amp OP attempts to make V1 into VIN, but because resistor R3 is directly connected to the output of op amp OP, a rise of V1 to the VIN level is suppressed according to the equation shown below, even if the op amp OP output voltage V2 rises to close to the power supply voltage VCC. When resistor R3 = 10 K , V1 will be suppressed to 0.031V even if the op amp OP output voltage is VCC (= 10V).

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That is to say, V1 is the voltage across the two sides of resistor R1, and therefore
V1 = (V2 - Vf) x R1/(R3 + R1)
= (V2 - Vf) x 33 /(10 K = 33)
= (10 - 0.6) x 33/10033 = 0.031

Therefore the base voltage V3 on the transistor TR2 becomes
V3 = V1 + Vf = 0.031 + 0.6 = 0.631V,

and is lower than normal, such that the current flowing to the LED row LED2 is reduced. Put another way, there is absolutely no incidence of overcurrent flowing to LED row LED2.

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In the meantime, the other LED row LED2 is in an open state; the open circuit case is shown in equivalent circuit 2(b). Transistor TR2 is equivalent to a diode D2 having a Vf = 0.6. Op amp OP, due to the virtual short, attempts to make V1 into VIN, but the transistor TR1 base is connected to ground through a diode and the resistor R1, so that even if op amp OP output voltage V2 rises to close to VCC, V1 does not reach VIN (0.5 V). Therefore even if the op amp maximum output voltage is 10V, the transistor TR1 base voltage V3 will be 0.63V.

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In other words, the voltage at V3 is Vf added to the voltage across the resistor R2 from V2, and therefore

$V3 = (V2 - Vf) \times R2/(R3 + R2) + Vf$
$= (10 - 0.6) \times 33/10033 + 0.6 = 0.63V.$

We then have
$V1 = V3 - VBE = 0.63 - 0.6 = 0.33V.$
Therefore the current I1 flowing to LED row LED1 is extremely reduced by means of the transistor TR1.

As a result of the above, when for some reason either LED 1 or LED2 of the LED row goes to an open state, current to the other LED row is reduced, thus preventing breakage of the other LED due to an overcurrent.

Here we describe the case in which the conventional LED drive circuit depicted in Fig. 7 is compared to the circuit of the present utility model. Normally, because the op amp OP positive phase input terminal and reverse phase input terminal are virtually shorted, V1 = VIN, and a current I1 = VIN/R1 flows to LED 1. Also, when R1 = R2 , a current I12 = I11 flows due to the transistor TR1 and TR2 current mirror configuration, such that a fixed and uniform current flows to each of LED1 and LED2.

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Here, when one of the LED1s is in an open state, the Fig. 8 equivalent circuit obtains. Op amp OP outputs a voltage V2 such that V1 becomes VIN. A current I11' of V1/R1 = 0.5/33 = 15.2 mA flows to R1, and a similar current flows between the base and emitter of the transistor TR1, which is equivalent to diode D11. At this point, because the current between the transistor TR1 base and emitter is larger than for the transistor TR2 base-emitter voltage VBE, VBE(TR1) will be greater than VBE(TR2).

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If we now let VBE(TR1) = 0.8V, VBE(TR2) = 0.6V, then

$V2 = V1 + VBE(TR1) = 0.5V + 0.8V = 1.3V$;
$I12' = (V2 - VBE(TR2))/R2 = (1.3 - 0.6)/33 = 21$ mA, which is larger than the initial current setting.

Therefore the other LED2 current increases and brightness increases, and there is a danger that the LED2 life will be shortened if LED2 light emission continues under these conditions.

When the other LED2 goes to an open state, there is no change in I1, and breakage is prevented.

0020

It is important in the present utility model that the bases of LED1 and LED2 current regulating transistors TR1 and TR2 are directly connected. One can conceive, for example, of a circuit in which, even though resistors R3A and R3B are interposed on the output side of the op amp OP, the bases of the current regulating transistors TR1 and TR2 for LED 1 and LED2 are not directly interconnected, and each is respectively regulated by the output of the op amp OP.

In this circuit, when LED1 goes to an open state, the Fig. 4 equivalent circuit obtains. At op amp OP, voltage V2 rises so that V1 becomes VIN. However, an R3A = 10K is connected [thereto], so that even if V2 rises to close to the op amp OP power supply voltage, V1 will not reach 0.5V.

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When V2 rises to close to the power supply voltage VCC (10V), the transistor TR2 becomes a simple emitter follower circuit, and current I2 becomes
$I2 = (VCC - VBE)/R2$
$= (10 - 0.6)/33 = 285$ mA;
an overcurrent will flow to the other LED2, resulting in breakage of LED2.

However, when LED2 goes to an open state, there will be no change in I1, and that breakage will be prevented.

0022

In the embodiment of the present utility model depicted in Fig. 1, transistors TR3 and TR4 are turned off when an OFF signal is input to the drive signal input terminal IN, such that power supply VCC is not supplied to the power supply line, and no power is supplied to the anode side of LED1 or LED2. It is therefore possible to reliably prevent leakage current in both LEDs 1 and 2, yielding an effective reduction in power consumption.

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In the present utility model, as shown in Fig. 5, when a particular LED3 is to be caused to emit light using a drive current different from that of LED1 and LED2, the particular LED3 current regulating transistor TR5 may also be driven using an op amp OP2 different from the op amp OP1 used to effect current regulation for LED1 and LED2. That is, by changing the value of the resistor R10 connected to the emitter of the current regulating transistor TR5, LED3 can be

caused to emit light using a current different from that [supplied] to LED1 and LED2. Also, a resistor R3' is here connected to the output terminal of the op amp OP2.

In this case, the LED1 and LED2 can be caused to emit light by equal drive currents and the LED3 caused to emit light by a different drive current. Even in this case, it goes without saying that breakage of one LED2 or LED1 can be prevented in case the other LED1 or LED2 goes to an open state.

In the present embodiment we have depicted an example of the present utility model in which the LED is used as a bar code reader light source. Clearly it can be similarly applied in an LED drive circuit for multiple LEDs used to form a surface light source.

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Effect of the Utility Model

In the utility model explained above, current regulating devices are respectively connected to LEDs connected in 2 rows; a resistor is placed between the output terminal of the op amp which controls each LED's drive current and the power supply regulation device, so that when one row of LEDs goes to an open state, the increase in LED current on the other row is suppressed by the connected resistor even if the op amp output voltage increases, and a reduction in life or breakage of other LEDs can be effectively prevented.

When the current regulating device is configured from bipolar transistors, the bases of the bipolar transistors used as the terminals of each current regulating element are directly connected, such that the current flow to each LED is equalized in a current mirror configuration, and a uniform and fixed current is caused to flow, enabling a uniform and fixed brightness of light to be emitted.

In this case, by selecting a resistance value for the resistor connected between the op amp output terminal and the bipolar transistor base which is sufficiently larger than the resistance value of the resistor connected to the emitter, the increase in base voltage when one of the LEDs goes to an open state can be effectively prevented, and the rise in current can be suppressed.

[END]